VERIFICATION OF A TRANSLATION

I, the below named translator, hereby declare that:

That my name is Satoshi ISHIKAWA;

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That I know well both the English and Japanese languages;

That I translated a Priority Document of Japanese Patent Application No. 2001-257420 filed on August 28, 2001, into the English language;

That the attached English language translation is a true and correct translation of the Priority Document of Japanese Patent Application No. 2001-257420 filed on August 28, 2001 I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Date: July 3, 2006

Satoshi ISHIKAWA

JAPAN PATENT OFFICE

This is to certify that the annexed is a true copy of the following application as filed with this Office.

Date of Application: August 28, 2001

Application Number: 2001-257420

JP 2001-257420

Applicant(s): Mitsubishi Chemical Corporation

June 23, 2006

Commissioner, Japan Patent Office: Makoto NAKAJIMA

Certification number: 2006-3046545

DOCUMENT NAME: Patent Application

REFERENCE NO.: J07389

FILING DATE: August 28, 2001

ADDRESS TO: Commissioner of Patent Office

INTERNATIONAL CLASSIFICATION: C09K 11/08

TITLE OF INVENTION: PHOSPHOR, LIGHT EMITTING DEVICE USING PHOSPHOR, AND DISPLAY AND LIGHTING SYSTEM USING LIGHT EMITTING DEVICE

NUMBER OF CLAIMS: 16

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INDICATION OF FEE:

NUMBER OF PAYMENT-IN-ADVANCE BOOK: 035035

AMOUNT OF PAYMENT-IN-ADVANCE: 21,000

LIST OF OBJECTS SUBMITTED:

OBJECT NAME:	Specification	1
OBJECT NAME:	Drawings	1
OBJECT NAME:	Abstract	1

REQUEST FOR PROOF: Yes

[Name of document] Specification

[Title of the invention]

PHOSPHOR, LIGHT EMITTING DEVICE USING PHOSPHOR, AND DISPLAY AND LIGHTING SYSTEM USING LIGHT EMITTING DEVICE

[Scope of the claim]

[Claim 1] A phosphor comprising a host material composed of a compound having a garnet crystal structure represented by the general formula (I):

$$M^1_aM^2_bM^3_cO_d \qquad (I)$$

wherein M^1 is a divalent metal element, M^2 is a trivalent metal element, M^3 is a tetravalent metal element, a is the number of 2.7 to 3.3, b is the number of 1.8 to 2.2, c is the number of 2.7 to 3.3, and d is the number of 11.0 to 13.0; and

a luminescent center ion incorporated in said host material.

[Claim 2] A phosphor according to claim 1, wherein the divalent metal element M^1 in the formula (I) is at least one element selected from the group consisting of Mg, Ca, Zn, Sr, Cd and Ba.

[Claim 3] A phosphor according to claim 2, wherein the divalent metal element M^1 in the formula (I) is Mg, Ca or Zn.

[Claim 4] A phosphor according to any one of claims 1 to 3, wherein the trivalent metal element M^2 in the formula (I) is at least one element selected from the group consisting of

Al, Sc, Ga, Y, In, La, Gd and Lu.

[Claim 5] A phosphor according to claim 4, wherein the trivalent metal element M^2 in the formula (I) is Al, Sc, Y or Lu.

[Claim 6] A phosphor according to any one of claims 1 to 5, wherein the tetravalent metal element M^3 in the formula (I) is at least one element selected from the group consisting of Si, Ti, Ge, Zr, Sn and Hf.

[Claim 7] A phosphor according to claim 6, wherein the tetravalent metal element M^3 in the formula (I) is Si, Ge or Sn.

[Claim 8] A phosphor according to any one of claims 1 to 7, wherein the luminescent center ion is at least one element selected from the group consisting of Cr, Mn, Fe, Co, Ni, Cu, Ce, Pr, Nd, Sm, Eu, Tb, Dy, Ho, Er, Tm and Yb.

[Claim 9] A phosphor according to claim 8, wherein the luminescent center ion is trivalent Ce.

[Claim 10] A phosphor according to any one of claims 1 to 9, wherein in the formula (I), the divalent metal element M^1 is Ca, the trivalent metal element M^2 is Sc, and the tetravalent metal element M^3 is Si.

[Claim 11] A phosphor according to any one of claims 1 to 9, wherein in the formula (I), the divalent metal element M^1 is Ca and Mg, the trivalent metal element M^2 is Sc and Y, or Sc and Lu, and the tetravalent metal element M^3 is Si.

[Claim 12] A phosphor according to any one of claims 1 to 11, wherein the amount of the luminescent center ion is 0.0001 to 0.3 mol based on a formula weight of the host material compound.

[Claim 13] A phosphor according to any one of claims 1 to 12, wherein when a light emitted therefrom is represented by XYZ color system, a sum of color coordinates x and y is not less than 0.6 [$(x+y) \geq 0.6$].

[Claim 14] A light emitting device comprising the phosphor as claimed in any one of claims 1 to 13 as a wavelength conversion material, and a semiconductor light emitting element capable of emitting a light in the range of from ultraviolet light to visible light.

[Claim 15] A display using the light emitting device as claimed in claim 14 as a light source.

[Claim 16] A lighting system using the light emitting device as claimed in claim 14 as a light source.

[Detailed description of the invention]

[0001]

[Technical field]

The present invention relates to a phosphor including a host material compound incorporating a luminescent center ion, and more particularly, to a phosphor which is useful as a wavelength conversion material capable of absorbing a light in the range of from ultraviolet light to visible

light and emitting a visible light having a longer wavelength than that of the absorbed light, and can provide a light emitting device having a high color rendering property when used in combination with a semiconductor light emitting element such as light emitting diodes (LED) and laser diodes (LD), a light emitting device using such a phosphor, and a display and a lighting system using such a light emitting device as a light source thereof.

[0002]

[Prior arts]

Hitherto, white light emitting devices constituted by the combination of a gallium nitride (GaN)-based blue light emitting diode as a semiconductor light emitting element and a phosphor as a wavelength conversion material have been noticed as a light emission source for displays or lighting systems because of a less consumption of electric power and a long service life thereof.

[0003]

In the white light emitting devices, the phosphor used therein absorbs a blue-range visible light emitted from the GaN-based blue light emitting diode, and emits a yellow light, so that a blue light unabsorbed by the phosphor is mixed with the yellow light, resulting in emission of the white light. As known in the art, the above phosphor typically includes a host material composed of an yttrium

and aluminum composite oxide ($Y_3Al_5O_{12}$), and cerium (Ce) incorporated as a luminescent center ion therein. The phosphor is not necessarily easily produced owing to its high calcination temperature, etc.

[0004]

[Subject to be solved by the Invention]

In view of the above prior arts, the present invention has been attained in order to develop a phosphor capable of not only being readily produced but also providing a light emitting device having a high color rendering property. An object of the present invention is to provide a phosphor capable of not only being readily produced but also providing a light emitting device having a high color rendering property, a light emitting device using the phosphor, and a display and a lighting system using the light emitting device as a light source thereof.

[0005]

[Means for the solution of the subject]

As a result of the present inventors' earnest studies for solving the above subject, it has been found that the above object can be achieved by the phosphor including a host material composed of a compound having a specific garnet crystal structure, and a luminescent center ion incorporated in the host material. The present invention has been attained on the basis of the above finding.

[0006]

That is, a gist of the present invention is to provide a phosphor comprising a host material composed of a compound having a garnet crystal structure represented by the general formula (I):

$$M^1_aM^2_bM^3_cO_d \qquad (I)$$

wherein M^1 is a divalent metal element, M^2 is a trivalent metal element, M^3 is a tetravalent metal element, a is the number of 2.7 to 3.3, b is the number of 1.8 to 2.2, c is the number of 2.7 to 3.3, and d is the number of 11.0 to 13.0; and

a luminescent center ion incorporated in said host material.

[0007]

[Embodiments of the invention]

The phosphor of the present invention contains a host material made of a compound having a garnet crystal structure represented by the above general formula (I). Specifically, the phosphor of the present invention is generally in the form of a composite oxide containing metal elements M^1, M^2 and M^3, and contains a host material composed of a compound having a known garnet crystal structure of $M^1_3M^2_2M^3_3O_{12}$, wherein M^1 is a divalent metal element, M^2 is a trivalent metal element, and M^3 is a tetravalent metal element.

[0008]

That is, although composite oxides such as, for example, the above $Y_3Al_5O_{12}$ are known as a host material of fluorescent substances, and compounds having a garnet structure wherein M^1 is a divalent metal element, M^2 is a trivalent metal element and M^3 is a tetravalent metal element are also known as described above, the present invention has been attained on the basis of such a finding that the compounds having a garnet structure wherein M^1 is a divalent metal element, M^2 is a trivalent metal element and M^3 is a tetravalent metal element can be excellently used as the host material of fluorescent substances, notwithstanding properties of the fluorescent substances are considerably varied depending upon constituting elements of the host material, valence thereof, etc.

[0009]

The divalent metal element M^1 in the formula (I) is usually at least one element selected from the group consisting of Mg, Ca, Zn, Sr, Cd and Ba from the viewpoint of good light emitting efficiency, preferably Mg, Ca or Zn, and more preferably Ca or a composite of Ca and Mg.

[0010]

The trivalent metal element M^2 in the formula (I) is usually at least one element selected from the group consisting of Al, Sc, Ga, Y, In, La, Gd and Lu from the

viewpoint of good light emitting efficiency, preferably Al, Sc, Y or Lu, and more preferably Sc, a composite of Sc and Y or a composite of Sc and Lu.

[0011]

The M^3 in the formula (I) represents a tetravalent metal element is usually at least one element selected from the group consisting of Si, Ti, Ge, Zr, Sn and Hf from the viewpoint of good light emitting efficiency, preferably Si, Ge or Sn, and more preferably Si.

[0012]

Also, as described above, the garnet crystal structure is generally a crystal structure with a body centered cubic lattice which is represented by the formula (I) wherein a is 3, b is 2, c is 3 and d is 12. However, in the present invention, any of the metal elements M^1, M^2 and M^3 may be replaced at the crystal lattice with an element constituting the luminescent center ion as described later, or the luminescent center ion element may be incorporated in an interstitial space between the crystal lattices. As a result, there is a garnet crystal structure that in the formula (I), a does not become 3, b does not become 2, c does not become 3 and d does not become 12. So, in the formula (I), a is in the range of 2.7 to 3.3, preferably 2.9 to 3.1, b is in the range of 1.8 to 2.2, preferably 1.95 to 2.05, c is in the range of 2.7 to 3.3, preferably 2.9 to 3.1,

and d is in the range of 11.0 to 13.0, preferably 11.65 to 12.35.

[0013]

The luminescent center ion incorporated in the compound having a garnet crystal structure as the host material is usually at least one di- to tetra-valent element selected from the group consisting of Cr, Mn, Fe, Co, Ni, Cu, Ce, Pr, Nd, Sm, Eu, Tb, Dy, Ho, Er, Tm and Yb, preferably divalent Mn, trivalent Ce, di- or tri-valent Eu or trivalent Tb, and more preferably trivalent Ce.

[0014]

The phosphor of the present invention can be produced by subjecting a pulverized mixture comprising a divalent metal element M^1-source compound, a trivalent metal element M^2-source compound, a tetravalent metal element M^3-source compound and a luminescent center ion-source compound, to heat-calcination treatment. The pulverized mixture may be prepared by the following methods. After pulverizing the above compounds using a dry pulverizer such as hammer mill, roll mill, ball mill and jet mill, the resultant pulverized compounds may be mixed together using a mixer such as ribbon blender, V-type blender and Henschel mixer, or after mixing the above compounds with each other, the resultant mixture may be pulverized using the dry pulverizer (in the dry method); or

after adding the above compounds to a medium such as water, the resultant mixture may be pulverized and mixed together using a wet pulverizer such as a medium-agitation type pulverizer, or after pulverizing the above compounds using the dry pulverizer, the resultant pulverized compounds may be added in a medium such as water, and
then the resultant mixture is mixed to prepare a slurry and further the obtained slurry may be spray-dried (in the wet method).

[0015]

Among these pulverizing and mixing methods, the use of the liquid medium is preferred because it is required to uniformly mix and disperse a small amount of the luminescent center ion-source compound in the whole mixture. The wet method is also preferred from the viewpoint of obtaining such a mixture, in which the other element-source compounds are uniformly mixed and dispersed. The above heat-calcination treatment may be conducted at a temperature of usually 1,000 to 1,600°C, preferably 1,200 to 1,500°C for 10 minutes to 24 hours under the atmosphere selected from atmospheric air, oxygen, carbon monoxide, carbon dioxide, nitrogen, hydrogen, argon or the like in a heat-resistant container composed of alumina or quartz such as crucible or tray. These gaseous atmospheres may be used singly or in the form of a mixture thereof. Meanwhile, after the heat-

calcination treatment, the obtained product may be further subjected to various treatments such as washing, drying and classification, if required.

[0016]

The heating atmosphere may be such an atmosphere required to obtain the ionic condition (ionic valence) contributing to light emission of the luminescent center ion element. For example, an oxidative or neutral atmosphere such as atmospheric air, oxygen, nitrogen and argon may be used in order to obtain trivalent Eu, etc., a weak-oxidative or weak-reducing atmosphere such as atmospheric air, carbon monoxide, carbon dioxide and nitrogen may be used in order to obtain trivalent Ce, etc., and a neutral or reducing atmosphere such as carbon monoxide, nitrogen, hydrogen and argon may be used in order to obtain divalent Mn, divalent Eu, trivalent Tb, etc.

[0017]

In addition, the M^1-source compound, M^2-source compound, M^3-source compound and luminescent center ion element-source compound may be in the form of oxides, hydroxides, carbonates, nitrates, sulfates, oxalates, carboxylates, halides or the like of the respective elements. The respective element-source compounds may be selected from these compounds in consideration of reactivity for producing the composite oxide as well as no formation of NOx, SOx,

etc., upon the calcination, or the like.

[0018]

When the divalent metal element M^1 is selected from Mg, Ca and Zn, specific examples of the M^1-source compound are as follows. That is, specific examples of the Mg-source compound may include MgO, $Mg(OH)_2$, $MgCO_3$, $Mg(OH)_2 \cdot 3MgCO_3 \cdot 3H_2O$, $Mg(NO_3)_2 \cdot 6H_2O$, $MgSO_4$, $Mg(OCO)_2 \cdot 2H_2O$, $Mg(OCOCH_3)_2 \cdot 4H_2O$, $MgCl_2$ or the like. Specific examples of the Ca-source compound may include CaO, $Ca(OH)_2$, $CaCO_3$, $Ca(NO_3)_2 \cdot 4H_2O$, $CaSO_4 \cdot 2H_2O$, $Ca(OCO)_2 \cdot H_2O$, $Ca(OCOCH_3)_2 \cdot H_2O$, $CaCl_2$ or the like. Specific examples of the Zn-source compound may include ZnO, $Zn(OH)_2$, $ZnCO_3$, $Zn(NO_3)_2$, $Zn(OCO)_2$, $Zn(OCOCH_3)_2$, $ZnCl_2$ or the like.

[0019]

When the trivalent metal element M^2 is selected from Al, Sc, Y and Lu, specific examples of the M^2-source compound are as follows. That is, specific examples of the Al-source compound may include Al_2O_3, $Al(OH)_3$, AlOOH, $Al(NO_3)_3 \cdot 9H_2O$, $Al_2(SO_4)_3$, $AlCl_3$ or the like. Specific examples of the Sc-source compound may include Sc_2O_3, $Sc(OH)_3$, $Sc_2(CO_3)_3$, $Sc(NO_3)_3$, $Sc_2(SO_4)_3$, $Sc_2(OCO)_6$, $Sc(OCOCH_3)_3$, $ScCl_3$ or the like. Specific examples of the Y-source compound may include Y_2O_3, $Y(OH)_3$, $Y_2(CO_3)_3$, $Y(NO_3)_3$, $Y_2(SO_4)_3$, $Y_2(OCO)_6$, YCl_3 or the like. Specific examples of the Lu-source compound may include Lu_2O_3, $Lu_2(SO_4)_3$, $LuCl_3$ or the like.

[0020]

When the tetravalent metal element M^3 is selected from Si, Ge and Sn, specific examples of the M^3-source compound are as follows. That is, specific examples of the Si-source compound may include SiO_2, H_4SiO_4, $Si(OCOCH_3)_4$ or the like. Specific examples of the Ge-source compound may include GeO_2, $Ge(OH)_4$, $Ge(OCOCH_3)_4$, $GeCl_4$ or the like. Specific examples of the Sn-source compound may include SnO_2, $SnO_2 \cdot nH_2O$, $Sn(NO_3)_4$, $Sn(OCOCH_3)_4$, $SnCl_4$ or the like.

[0021]

When the luminescent center ion element is selected from Mn, Ce, Eu and Tb, specific examples of the luminescent center ion element-source compound are as follows. That is, specific examples of the Mn-source compound may include MnO_2, Mn_2O_3, Mn_3O_4, MnOOH, $MnCO_3$, $Mn(NO_3)_2$, $MnSO_4$, $Mn(OCOCH_3)_2$, $Mn(OCOCH_3)_3$, $MnCl_2$, $MnCl_3$ or the like. Specific examples of the Ce-source compound may include Ce_2O_3, CeO_2, $Ce(OH)_3$, $Ce(OH)_4$, $Ce_2(CO_3)_3$, $Ce(NO_3)_3$, $Ce_2(SO_4)_3$, $Ce(SO_4)_2$, $Ce_2(OCO)_6$, $Ce(OCOCH_3)_3$, $CeCl_3$, $CeCl_4$ or the like. Specific examples of the Eu-source compound may include Eu_2O_3, $Eu_2(SO_4)_3$, $Eu_2(OCO)_6$, $EuCl_2$, $EuCl_3$ or the like. Specific examples of the Tb-source compound may include Tb_2O_3, Tb_4O_7, $Tb_2(CO_3)_3$, $Tb_2(SO_4)_3$, $TbCl_3$ or the like.

[0022]

The phosphor of the present invention comprising a host material composed of a compound having a garnet crystal structure, contains the luminescent center ion in an amount of usually 0.0001 to 0.3 mol, preferably 0.001 to 0.15 mol based on a formula weight of the compound as the host material thereof. When the content of the luminescent center ion is less than the above-specified range, the emission intensity of the resultant phosphor tends to be lowered. On the other hand, when the content of the luminescent center ion is more than the above-specified range, the emission intensity of the resultant phosphor also tends to be reduced owing to such a phenomenon called "concentration quenching".

[0023]

In the case where the phosphor of the present invention is used as a wavelength conversion material, the phosphor, for example, containing trivalent Ce as the luminescent center ion, absorbs a light in the range of from ultraviolet light to blue-region visible light, and emits a visible light having a longer wavelength than that of the absorbed light, such as green light, yellow light, orange light, red light or a light exhibiting an intermediate color thereof. When only the light emitted from the phosphor except for a scattered component of excitation light therefor is measured by spectroscopic method to represent the color of the

emitted light by XYZ color system according to JIS Z8701, a sum of color coordinates x and y is preferably not less than 0.6 ($(x+y) \geq 0.6$), more preferably not less than 0.8 ($(x+y) \geq 0.8$).

[0024]

The light emitting device of the present invention includes the above phosphor as a wavelength conversion material, and a semiconductor light emitting element such as LED and LD. The light emitting device is a high-color-rendering light emitting device capable of absorbing a light in the range of from ultraviolet light to a visible light, which is emitted from the semiconductor light emitting element, and emitting a visible light having a longer wavelength than that of the absorbed light. The light emitting device may be suitably used as a light source for displays such as color liquid crystal displays, or lighting systems such as surface-emitting type lighting systems.

[0025]

Next, the light emitting device of the present invention is explained by referring to the accompanying drawings. Fig. 2 is a schematic sectional view showing an example of a light emitting device constituted from the phosphor of the present invention as a wavelength conversion material, and a semiconductor light emitting element. Fig. 3 is a schematic sectional view showing an example of a

surface-emitting lighting system into which the light emitting devices shown in Fig. 3 are incorporated. As shown in Figs. 2 and 3, the reference number 1 represents the light emitting device, the reference number 2 represents a mount lead, the reference number 3 represents an inner lead, the reference number 4 represents the light emitting element, the reference number 5 represents a phosphor-containing resin, the reference number 6 represents a conductive wire, the reference number 7 represents a molding material, the reference number 8 represents the surface-emitting lighting system, the reference number 9 represents a diffusion plate, and the reference number 10 represents a rectangular retaining casing.

[0026]

As shown in Fig. 2, the light emitting device 1 of the present invention has a generally shell-like shape. A semiconductor light emitting element 4 made of a GaN-based blue light emitting diode, etc., is disposed within an upper cup portion of a mount lead 2, and an upper surface of the light emitting element 4 is covered with a phosphor-containing resin 5 which is formed by pouring a mixture prepared by mixing and dispersing the phosphor of the present invention with a binder such as epoxy resin and acrylic resin, into the upper cup portion. The semiconductor light emitting element 4 and the mount lead 2,

and the semiconductor light emitting element 4 and an inner lead 3, are respectively electrically connected with each other by conductive wires 6, 6. These elements are wholly covered and protected by a molding material 7 composed of epoxy resin, etc.

[0027]

In addition, as shown in Fig. 3, the surface-emitting lighting system 8 into which a plurality of the light emitting devices 1 are incorporated, includes a rectangular retaining casing 10 having a light-impermeable inside surface such as a white smooth surface, a number of the light emitting devices 1 arranged on a bottom surface of the casing 10, and a diffusion plate 9 such as an opaque white acrylic resin plate which is fixed to a position corresponding to a lid for the casing 10 to equalize a light emitted from the light emitting devices. Meanwhile, although power sources, circuits, etc., for operating the light emitting devices 1 are arranged outside the respective light emitting devices, these members are omitted from the figures for simplicity.

[0028]

When a voltage is applied to the semiconductor light emitting element 4 of the respective light emitting devices 1 by operating the surface-emitting lighting system 8, a part of a light emitted therefrom such as blue light is

absorbed by the phosphor of the present invention contained as a wavelength conversion material in the phosphor-containing resin portion 5, so that a light having a longer wavelength is emitted from the phosphor. The light emitted from the phosphor is mixed with a light unabsorbed by the phosphor such as blue light to obtain a mixed light having a higher color rendering property. The thus obtained light is transmitted through the diffusion plate 9 and then irradiated in the upward direction when viewed in the figure. At this time, the light is equalized within the diffusion plate 9 of the retaining casing 10, so that a light having a uniform luminous intensity can be emitted from the lighting system.

[0029]

[Examples]

The present invention is described in more detail by Examples, but the Examples are only illustrative and not intended to limit the scope of the present invention.

[0030]

Example 1:

0.0297 mol of $CaCO_3$ as a M^1-source compound, 0.01 mol of Sc_2O_3 as a M^2-source compound, 0.03 mol of SiO_2 as a M^3-source compound and 0.0003 mol of $Ce(OCOCH_3)_3$ as a luminescent center ion element-source compound were pulverized and mixed together with pure water in a wet ball

mill including an alumina container and beads, dried and then passed through a nylon mesh. The resultant pulverized mixture was heat-calcined in an alumina crucible under atmospheric air at 1,400°C for 2 hours, and successively subjected to water-washing, drying and classification, thereby producing a phosphor.

[0031]

As a result of analyzing the thus obtained phosphor by powder X-ray diffraction method, it was confirmed that the phosphor contained a host material composed of a compound of a garnet crystal structure having a composition as shown in Table 1, and trivalent Ce as a luminescent center ion incorporated in the host material. Further, the phosphor was subjected to measurements of emission spectrum and excitation spectrum thereof. The results are shown in Fig. 1. From the thus measured emission spectrum, the color coordinates x and y in XYZ color system prescribed in JIS Z8722 were calculated assuming that the wavelength interval was 5 nm. As a result, x was 0.28 (x=0.28), y was 0.54 (y=0.54), and a sum of x and y was 0.82 ((x+y)=0.82). Further, the phosphor was irradiated with a blue light emitted from a GaN-based blue light emitting diode (peak wavelength: 465 nm), while controlling an irradiation intensity thereof. As a result, the phosphor absorbed the blue light and emitted a yellowish green color light, and

further the emitted yellowish green light was then mixed with a blue light unabsorbed by the phosphor, resulting in emission of a bluish white light.

[0032]

Example 2:

The same procedure as defined in Example 1 was conducted except that 0.0147 mol of $CaCO_3$ and 0.015 mol (as Mg) of $Mg(OH)_2 \cdot 3MgCO_3 \cdot 3H_2O$ were used as a M^1-source compound, and 0.0075 mol of Sc_2O_3 and 0.0025 mol of Y_2O_3 were used as a M^2-source compound, thereby producing a phosphor. As a result of analyzing the thus obtained phosphor by powder X-ray diffraction method, it was confirmed that the phosphor contained a host material composed of a compound of a garnet crystal structure having a composition as shown in Table 1, and trivalent Ce incorporated as a luminescent center ion in the host material. Further, the phosphor was subjected to measurements of emission spectrum and excitation spectrum thereof. The results are shown in Fig. 2. From the thus measured emission spectrum, the color coordinates x and y were calculated by the same method as in Example 1. As a result, it was confirmed that x was 0.43 (x=0.43), y was 0.53 (y=0.53), and a sum of x and y was 0.96 ((x+y)=0.96). Further, the phosphor was irradiated with a blue light by the same method as in Example 1, while controlling an irradiation intensity thereof. As a result, the phosphor

absorbed the blue light and emitted a yellow color light, and further the emitted yellow light was then mixed with a blue light unabsorbed by the phosphor, resulting in emission of a white light.

[0033]

Example 3:

The same procedure as defined in Example 1 was conducted except that the heat-treating temperature was changed to 1,200°C, thereby producing a phosphor. As a result of analyzing the thus obtained phosphor by powder X-ray diffraction method, it was confirmed that the phosphor contained a host material composed of a compound of a garnet crystal structure having a composition as shown in Table 1, and trivalent Ce incorporated as a luminescent center ion in the host material. From the measured emission spectrum of the phosphor, the color coordinates x and y were calculated by the same method as in Example 1. As a result, it was confirmed that x was 0.28 (x=0.28), y was 0.54 (y=0.54), and a sum of x and y was 0.82 ((x+y)=0.82). Further, the phosphor was irradiated with a blue light by the same method as in Example 1, while controlling an irradiation intensity thereof. As a result, the phosphor absorbed the blue light and emitted a yellowish green color light, and further the emitted yellowish green light was then mixed with a blue light unabsorbed by the phosphor, resulting in emission of a

bluish white light.

[0034]

Example 4:

The same procedure as defined in Example 2 was conducted except that 0.0050 mol of Sc_2O_3 and 0.0050 mol of Y_2O_3 were used as a M^2-source compound, thereby producing a phosphor. As a result of analyzing the thus obtained phosphor by powder X-ray diffraction method, it was confirmed that the phosphor contained a host material composed of a compound of a garnet crystal structure having a composition as shown in Table 1, and trivalent Ce incorporated as a luminescent center ion in the host material. From the measured emission spectrum of the phosphor, the color coordinates x and y were calculated by the same method as in Example 1. As a result, it was confirmed that x was 0.47 (x=0.47), y was 0.50 (y=0.50), and a sum of x and y was 0.97 ((x+y)=0.97). Further, the phosphor was irradiated with a blue light by the same method as in Example 1, while controlling an irradiation intensity thereof. As a result, the phosphor absorbed the blue light and emitted a yellow color light, and further the emitted yellow light was then mixed with a blue light unabsorbed by the phosphor, resulting in emission of a white light.

[0035]

Example 5:

The same procedure as defined in Example 2 was conducted except that 0.0050 mol of Sc_2O_3 and 0.0050 mol of Lu_2O_3 were used as a M^2-source compound, thereby producing a phosphor. As a result of analyzing the thus obtained phosphor by powder X-ray diffraction method, it was confirmed that the phosphor contained a host material composed of a compound of a garnet crystal structure having a composition as shown in Table 1, and trivalent Ce incorporated as a luminescent center ion in the host material. From the measured emission spectrum of the phosphor, the color coordinates x and y were calculated by the same method as in Example 1. As a result, it was confirmed that x was 0.45 (x=0.45), y was 0.53 (y=0.53), and a sum of x and y was 0.98 ((x+y)=0.98). Further, the phosphor was irradiated with a blue light by the same method as in Example 1, while controlling an irradiation intensity thereof. As a result, the phosphor absorbed the blue light and emitted a yellow color light, and further the emitted yellow light was then mixed with a blue light unabsorbed by the phosphor, resulting in emission of a white light.

[0036]

Example 6:

The same procedure as defined in Example 1 was conducted except that 0.0147 mol of $CaCO_3$ and 0.015 mol of ZnO were used as an M^1-source compound, thereby producing a

phosphor. As a result of analyzing the thus obtained phosphor by powder X-ray diffraction method, it was confirmed that the phosphor contained a host material composed of a compound of a garnet crystal structure having a composition as shown in Table 1, and trivalent Ce incorporated as a luminescent center ion in the host material. From the measured emission spectrum of the phosphor, the color coordinates x and y were calculated by the same method as in Example 1. As a result, it was confirmed that x was 0.29 (x=0.29), y was 0.54 (y=0.54), and a sum of x and y was 0.83 ((x+y)=0.83). Further, the phosphor was irradiated with a blue light by the same method as in Example 1, while controlling an irradiation intensity thereof. As a result, the phosphor absorbed the blue light and emitted a yellowish green color light, and further the emitted yellowish green light was then mixed with a blue light unabsorbed by the phosphor, resulting in emission of a bluish white light.

[0037]

Table 1

Examples	Composition of phosphor
Example 1	$(Ca_{0.99})_3Sc_2Si_3O_{12.015}:Ce^{3+}$
Example 2	$(Ca_{0.49}Mg_{0.50})_3(Sc_{0.75}Y_{0.25})_2Si_3O_{12.015}:Ce^{3+}$
Example 3	$(Ca_{0.99})_3Sc_2Si_3O_{12.015}:Ce^{3+}$
Example 4	$(Ca_{0.49}Mg_{0.50})_3(Sc_{0.50}Y_{0.50})_2Si_3O_{12.015}:Ce^{3+}$
Example 5	$(Ca_{0.49}Mg_{0.50})_3(Sc_{0.50}Lu_{0.50})_2Si_3O_{12.015}:Ce^{3+}$
Example 6	$(Ca_{0.49}Zn_{0.50})_3Sc_2Si_3O_{12.015}:Ce^{3+}$

[0038]

[Effect of the invention]

According to the present invention, there are provided a phosphor that is readily produced and can provide a high-color-rendering light emitting device, a light emitting device using the phosphor, and a display and a lighting system using the light emitting device as a light source.

[BRIEF DESCRIPTION OF THE DRAWINGS]

Fig. 1 is a graph showing an emission spectrum and an excitation spectrum of a phosphor obtained in Example 1 according to the present invention.

Fig. 2 is a graph showing an emission spectrum and an excitation spectrum of a phosphor obtained in Example 2 according to the present invention.

Fig. 3 is a schematic sectional view showing an example of a light emitting device constituted from the phosphor of the present invention as a wavelength conversion material, and a semiconductor light emitting element.

Fig. 4 is a schematic sectional view showing an example of a surface-emitting lighting system into which the light emitting devices shown in Fig. 3 are incorporated.

[Explanation for the reference]

1: light emitting device

2: mount lead

3: inner lead

4: semiconductor light emitting element

5: phosphor-containing resin

6: conductive wire

7: molding material

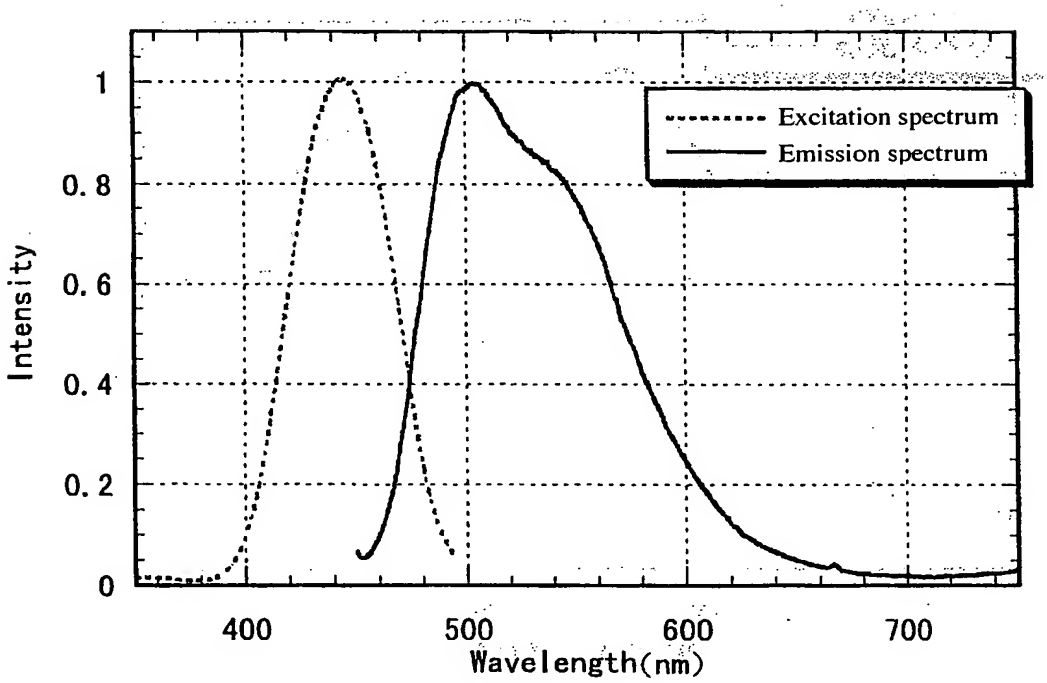
8: surface-emitting lighting system

9: diffusion plate

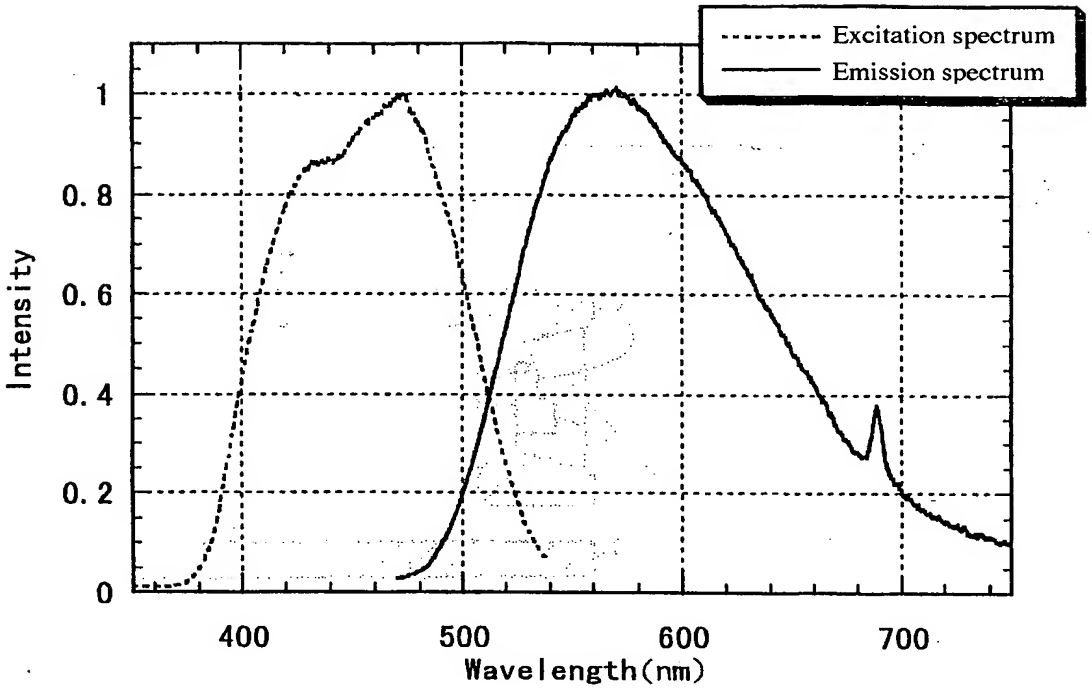
10: retaining casing

[Name of Document] Drawings

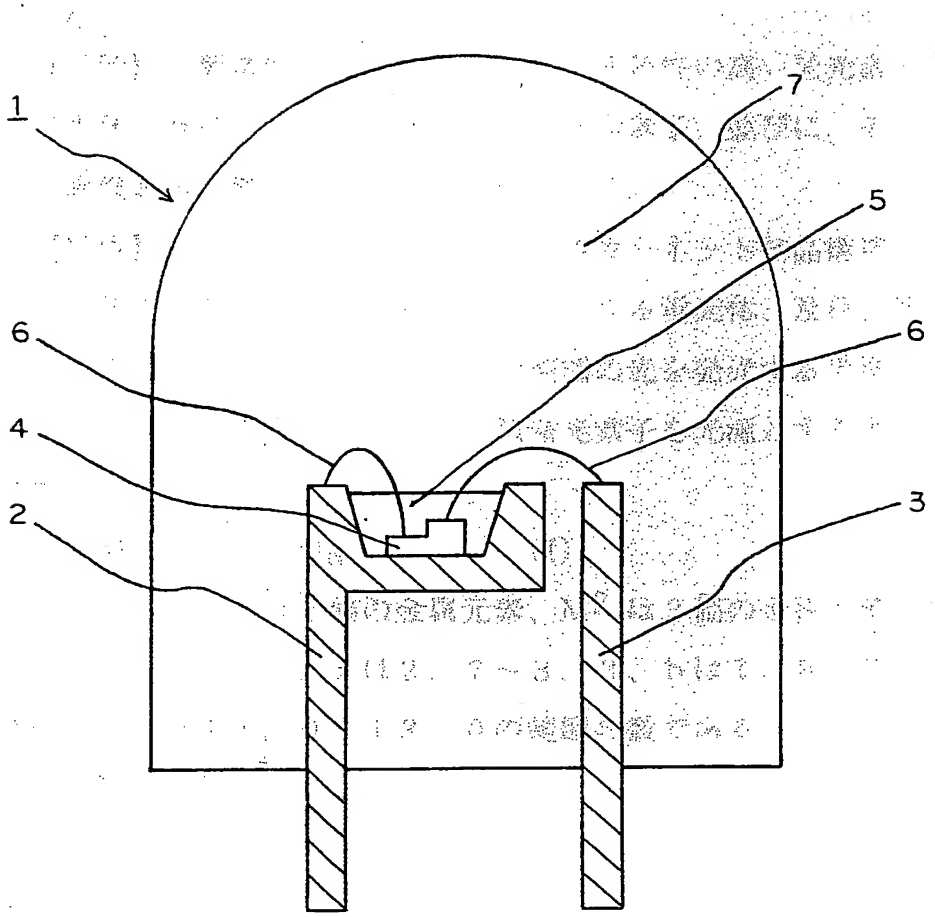
[Fig. 1]



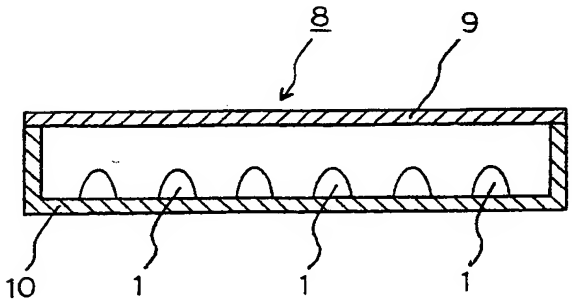
[Fig. 2]


Excitation spectrum
Emission spectrum
Intensity
1
0.8
0.6
0.4
0.2
0
400
500
600
700
Wavelength(nm)

[Fig. 3]



[Fig. 4]



[Name of document] Abstract

Purpose: An object of the present invention is to provide a phosphor capable of not only being readily produced but also providing a light emitting device having a high color rendering property, a light emitting device using the phosphor, and a display and a lighting system using the light emitting device as a light source thereof.

Constitution: A phosphor comprising a host material composed of a compound having a garnet crystal structure represented by the general formula (I):

$$M^1_aM^2_bM^3_cO_d \qquad (I)$$

(wherein M^1 is a divalent metal element, M^2 is a trivalent metal element, M^3 is a tetravalent metal element, a is the number of 2.7 to 3.3, b is the number of 1.8 to 2.2, c is the number of 2.7 to 3.3, and d is the number of 11.0 to 13.0), and a luminescent center ion incorporated in the host material; a light emitting device comprising the phosphor as a wavelength conversion material and a semiconductor light emitting element capable of emitting a light in the range of from ultraviolet light to visible light; and a display and a lighting system using the light emitting device as a light source.

[Selected figure] None